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# *Indian Standard*

# CODE OF PRACTICE FOR TREATMENT OF WATER FOR LOW AND MEDIUM PRESSURE LAND BOILERS

## *( Third Revision )*

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Gr 5 *March* 1983

**IS : 1680 - 1982**

# *Indian Standard*
# CODE OF PRACTICE FOR TREATMENT OF WATER FOR LOW AND MEDIUM PRESSURE LAND BOILERS
## *( Third Revision )*

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# AMENDMENT NO. 1 JANUARY 2009
# TO
# IS 1680 : 1982 CODE OF PRACTICE FOR TREATMENT OF WATER FOR LOW AND MEDIUM PRESSURE LAND BOILERS

***( Third Revision )***

[*Page* 12, *clause* **5.1.1.2**(c)] — Insert the following after (c):

‘(d) Ion exchange methods as mentioned above at point nos. a), b) and c) are preferable compared to other methods since they give better quality water, ease of operation with less waste generation, and are economical.’

(CHD 13)

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Reprography Unit, BIS, New Delhi, India

# *Indian Standard*

# CODE OF
# PRACTICE FOR TREATMENT OF WATER FOR LOW AND MEDIUM PRESSURE LAND BOILERS

## ( *Third Revision* )

## 0. FOREWORD

**0.1** This Indian Standard ( Third Revision ) was adopted by the Indian Standards Institution on 31 December 1982, after the draft finalized by the Boiler Water Sectional Committee had been approved by the Chemical Division Council.

**0.2** There are two sides to a boiler; the fire side and the water side. Usually much care is devoted on keeping the fire side free from accumulations of deposits that would tend to interfere with adequate heat transfer. However, in spite of availability of many simple forms of modern water treatment in many of the low pressure boilers, little attempt is made to keep the water side free from deposits. Scale on the water side can be far more dangerous than deposits on the fire side. This may result in overheating of the metal and consequent failure and risk of explosion.

**0.3** This standard lays down conditions to be aimed at in boiler feed water and boiler water to overcome the troubles experienced on the water side of the boilers. Whist boilers operating at higher pressures are usually attended by qualified works chemists, low pressure boilers usually receive little attention. Particular attention has, therefore, been given in this standard to the needs of operators of low pressure boilers, that is, those operating below 20 $MN/m^2$ ( 20 $kgf/cm^2$ ) pressure. Quality requirement for boiler feeds and methods for treatment suitable for boilers working under higher pressure up to 5.9 $MN/m^2$ ( 60 $kgf/cm^2$ ) have also been given but it is recommended that advice of technical specialists in the treatment of water as also of boiler makers should be obtained to determine the special form of treatment suitable to meet the particular requirements. Whenever available, advice of these specialists may also be sought in operating low pressure boilers.

**0.4** This standard was first issued in 1960. It was first revised in 1968 to include methods for elimination of oil in boiler water and to change the limits of dissolved oxygen and *p*H. It was revised second time in 1976 to include specific objects and methods for water treatment. This third revision is being issued to make it generally applicable to boilers having pressure up to 5.9 $MN/m^2$ instead of 4.1 $MN/m^2$ covered by IS : 1680-1976*. Also the recommended chemical composition of feed water and boiler water given in IS : 1680-1976* has not been included in this third revision. Instead IS : 10392-1982† lays down the specifications of feed water and boiler water for low and medium pressure boilers.

**0.5** In preparing this code, assistance has been derived from BS 2486 : 1964 'Treatment of water for land boilers', issued by the British Standards Institution.

**0.6** For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960‡. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

## 1. SCOPE

**1.1** This standard deals with the chemical methods of attaining the conditions to be aimed at for water for land boilers in order to overcome the troubles on the water side of boilers operating up to 2.0 $MN/m^2$ ( 20 $kgf/cm^2$ ) pressure. It also, applies generally to boilers operating under medium pressure, that is, between 2.0 and 5.9 $MN/m^2$ ( 20 and 60 $kgf/cm^2$ ).

**1.2** Land boilers operating at pressure higher than 5.9 $MN/m^2$ ( 60 $kgf/cm^2$ ) marine boilers and locomotive boilers are not covered in this standard.

## 2. IMPURITIES IN WATER

**2.1** A really satisfactory boiler feed water supply is never obtained free in nature. Rain water dissolves soluble gases from the air and as it begins to flow over the earth's surface or through its strata, it takes up more

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*Code of practice for treatment of water for land boilers ( *second revision* ).

†Specification for feed water and boiler water for low and medium pressure land boilers.

‡Rules for rounding off numerical values ( *revised* )

impurities, such as mineral salts, organic matter and clay. The water thus obtained in nature may contain the following:

a) Dissolved gases,

b) Dissolved solids,

c) Suspended solids, and

d) Living organisms.

**2.1.1** *Dissolved Gases* — Rain water as it descends to the earth takes up oxygen, nitrogen and carbon dioxide from the air. The water also picks up carbon dioxide from decaying organic matter on the surface of the ground. Oxygen and carbon dioxide can cause corrosion and have, therefore, to be removed from feed water. Nitrogen is an inert gas and does not affect boilers. Carbon dioxide dissolves chalk or limestone; magnesium carbonate is also similarly dissolved. Calcium and magnesium bicarbonates are thus obtained in varying amounts in almost every natural water.

**2.1.2** *Dissolved Solids* — Salts usually present in the dissolved state in natural water are those of sodium, calcium and magnesium. Salts of sodium are harmless unless present in very large quantity. Natural waters also contain varying amounts of silica. Iron is often present in the form of ferrous iron ( $Fe^{++}$ ) which is converted to the thermodynamically stable ferric iron ( $Fe^{+++}$ ) in the presence of dissolved oxygen in the *p*H range of natural waters. The oxidized ferric iron is brown in colour.

**2.1.2.1** The most important dissolved salts from the point of view of boiler feed are those of calcium and magnesium. Their presence makes water hard and a deposit or scale is obtained by the use of such water in boilers. Silica also is important, particularly in the case of high pressure boilers, as it forms a hard scale. Further, silica may be steam volatile, creating problems with turbine blades.

**2.1.2.2** In addition to the bicarbonates mentioned in **2.1.1**, carbonates, hydroxides, chlorides, sulphates and nitrates of calcium, magnesium and other heavy metals may also be present in water. The bicarbonates, carbonates and hydroxides of calcium and magnesium give rise to 'alkaline' or 'carbonate' hardness and the chlorides, sulphates and nitrates to 'non-alkaline' or 'non-carbonate' hardness. The terms temporary and permanent hardness are now discarded and have been replaced by carbonate and non-carbonate hardness respectively.

**2.1.2.3** The hardness of water is expressed in different forms. The form of expression followed in this standard is milligrams of calcium carbonate per litre of water. Although the hardness may be actually due to soluble salts of calcium, magnesium, iron, manganese aluminium or other heavy metals, the result is expressed as milligrams per litre of calcium carbonate.

**2.1.3** *Suspended Solids* — Impurities which are held in suspension and can be removed by sedimentation and filtration are mostly in the form of clay, silt, insoluble inorganic salts, organic matter or precipitated iron salts. They may get deposited in feedlines, economisers and boilers and sometimes cause foaming in boilers.

**2.1.4** *Living Organisms* — Living organisms are present in varying numbers in all natural waters.

**2.2 Oils and Grease** — Sometimes oils and grease find their way into water used for boiler feed. Oils and greases are bad conductors of heat and when they form a film on the boiler plate or tube, they interfere with free transfer of heat to the water with the result that overheating takes place at some portions which may produce bulging or even bursting. Besides they also cause foaming in boilers.

## 3. SOURCES OF WATER

**3.1** Water is obtained from different sources in nature and its composition is also found to differ widely with its source. It is, therefore, necessary to study the characteristics of these supplies to treat them properly to obtain a supply of desired quality. The usual sources of water are:

a) *Surface Water* — from rivers, streams or lakes, and
b) *Underground Water* — from wells and springs.

**3.1.1** *Surface Water* — As water flows over the earth, it dissolves salts of sodium, potassium, calcium, magnesium, iron and aluminium, besides silica and traces of manganese and other heavy metals. In addition to these dissolved impurities, surface water, particularly river water, contains significant concentrations of various colloidal clays of siliceous origin, referred to as turbidity. Turbidity is very high in rainy season. It also contains to a lesser degree hydrophilic and hydrophobic colloids of sewage and vegetative origin, depending on the degree of pollution from domestic and industrial waste waters. It contains carbonate and non-carbonate hardness in varying proportions. Iron, if present, may be in soluble or insoluble state.

**3.1.2** *Underground Water* — The character of underground water depends upon the strata through which it has passed. Usually, it contains both carbonate as well as non-carbonate hardness. Underground waters in general are rich in free carbon dioxide and in bicarbonates. Silica content is sometimes high. In many cases iron and manganese are present along with bicarbonates.

## 4. OBJECT OF TREATMENT

**4.1** When water is evaporated in a boiler, dissolved salts are concentrated and insoluble salts are precipitated. They may either separate out in the form of a non-adhering soft sludge which can be removed without difficulty or they may deposit on the sides of the boiler and the tubes as a firmly adhering scale. Accumulation of scale and deposit formation on heating surfaces considerably reduces the rate of heat transfer and introduces the risk of overheating and failure of effected surfaces. The effect of scale becomes more serious as the boiler pressure and heat transfer rates increase to a point when temperatures approach more closely the upper safe value for the materials used

**4.2** Corrosion destroys the metal causing serious damage to the boiler. The corrosiveness of water is determined by the nature of salts present in it, *p*H and dissolved oxygen content. Under boiler conditions, concentrated alkalis and nitrates can also attack steel. The effect of neutral salts on corrosion is complex, but chlorides are known to increase it. It shall be remembered, however, that water of high purity may even be more corrosive than raw water, especially in presence of dissolved oxygen. The most objectionable consequences of corrosion are:

a) loss of mechanical strength arising from general thinning of the metal or development of cracks,
b) pitting or perforation of the metal,
c) contamination of the water, and
d) interference with heat transfer.

**4.3** Condensate can become corrosive as a result of the presence of certain gaseous impurities in the steam, since the impurities dissolve in the condensate as it is formed. The gaseous, impurities that may be formed in the boiler are carbon dioxide, oxygen, ammonia, hydrogen sulphide, sulphur dioxide and hydrogen. Of these carbon dioxide and oxygen are of greater significance in practice. Under certain conditions the water in the boiler produces foam, and a certain portion of it is carried forward by steam. This causes damage to fittings using steam.

**4.4** Water before use may, therefore, require treatment for:

a) removal of suspended matter,
b) prevention of scale,
c) prevention of corrosion and caustic embrittlement,
d) elimination of certain gases,
e) prevention of foaming, and
f) removal of grease and oils.

## 5. TREATMENT OF FEED WATER

**5.0** The treatment to be employed to obtain the desired results is generally effected in the following three stages:

a) *Pretreatment* — Pretreatment for removal of suspended solids, organic matter and colloidal silica, wherever necessary;

b) *Softening* — Treatment of raw water to prevent scale formation, and

c) *Conditioning* — Addition of small quantities of chemicals to the final feed water or into the boiler drum, if necessary, to adjust its composition to meet particular conditions of the boiler plant:

**5.0.1** Removal of oil or grease, when necessary, is effected either along with softening or separately but before conditioning.

**5.1 Softening** — Softening may be effected by either of two following methods:

a) *By External Treatment* — Treatment in a separate plant to remove scale forming salts before feeding the water to boiler, or

b) *By Internal Treatment* - Addition of chemicals to the boiler feed whereby scale forming salts are precipitated in the boiler itself in the form of a smooth flowing sludge.

**5.1.1** *External Treatment* — Three methods are available for softening water exernally, namely, (a) precipitation method, (b) exchange method, and (c) distillation method.

**5.1.1.1** *Softening by precipitation methods* — In the precipitation methods, hardness and carbon dioxide are reduced; the precipitates are then separated by sedimentation and filtration:

a) *Lime-soda process* — The oldest and the most widespread method of precipitation softening is the lime-soda process, hot and cold. In this process, water is treated with hydrated lime ( calcium hydroxide ) and soda ash ( sodium carbonate ).

*Hydrated lime treatment* — In theory, treatment with hydrated lime removes calcium carbonate hardness and uncombined carbon dioxide by precipitation in the form of calcium carbonate. At the same time magnesium carbonate hardness is removed by precipitation in the form of magnesium hydroxide. Another reaction of a slightly different type takes place between hydrated lime and magnesium non-carbonate hardness. In this reaction, magnesium non-carbonate hardness is removed by precipitation in the form of magnesium hydroxide and replaced by an equivalent amount of calcium non-carbonate hardness. The calcium non-carbonate hardness produced in this way together with that originally present in raw water is removed by treatment with sodium carbonate. In practice the chemical reaction between lime and magnesium hardness may not go to completion. When waters containing sodium bicarbonate are treated with hydrated lime, sodium bicarbonate is converted into sodium carbonate.

*Sodium carbonate treatment* — Treatment with sodium carbonate causes non-carbonate hardness to precipitate from solution in the form of calcium and magnesium carbonate. The calcium and magnesium salts are replaced by an equivalent amount of sodium salts. Thus, by means of treatment with hydrated lime and sodium carbonate in appropriate quantities, most of the carbonate and non-carbonate hardness can be removed and soft water produced with hardness of approximately 10 to 40 mg/1 in terms of calcium carbonate.

*Coagulants* — A big advance was made in the field of precipitation softening with the introduction of coagulants. The coagulants generally used are sodium aluminate, magnesium oxide, alum, etc. The amount of coagulant used is normally very small and is always less than 50 mg/1 of the water being treated. It is added to the lime-soda mixture. The following improvements are obtained:

1) Magnesium is precipitated more efficiently, thus preventing, after precipitation, a difficulty associated with precipitation softening;
2) Less lime is required to complete the softening reactions;
3) Hardness of the softened water is reduced to less than 20 mg/1 in terms of calcium carbonate;
4) Sedimentation is accelerated, and softened water of low suspended solids is passed to the filters; and
5) Silica content of the softened water is generally reduced.

Rapid flocculation and sedimentation may be used to reduce the retention time, and this is valuable where a plant has to be overloaded. Another refinement which improves the characteristics of softened water is the establishment, in the softener, of a blanket of sludge through which the chemicals and the water are made to pass after leaving the mixing zone. Provided no short-circuiting takes place, a water of lower hardness and with less suspended solids may be produced. Another improvement with regard to precipitation softening is 'sludge return' or 'sludge recirculation'. A small quantity of sludge is continuously withdrawn from the sludge zone of the softener and added to the incoming mixture of water and reagents. The return sludge gives a seeding effect to both flocculation and precipitation and results in better sedimentation and better softening.

*Partial softening* — When a fully softened water is not required, it may be partially softened by treatment with hydrated lime alone to precipitate a major part of the carbonate hardness, according to the degree of softening required.

*Hot softening* — The efficiency of any precipitation process of water softening increases considerably with rise in temperature but the degree of improvement is most marked in the lower temperature range ( up to about 50°C ). The heat may be derived from waste steam, or live steam or water drawn from the boiler. If boiler water is returned to the softener, some modification of chemical charges will be required. Boiler water containing sodium orthophosphate sometimes retards the softening reactions when the temperature at the softener is below 70°C and *p*H is less than 9.

b) *Phosphate softening* — Phosphate softening is employed only in high pressure boilers which are beyond the scope of this standard. When used with caustic soda, sodium phosphate produces water of very low residual hardness. The process is usually carried out at a high temperature ( near to or above 100°C ).

**5.1.1.2** *Exchange methods of softening* — If water containing calcium and magnesium salts in solution is passed through a bed of ion exchange materials, synthetic or natural, calcium and magnesium are retained by the material and are replaced by sodium so that the water leaving the mineral bed contains sodium salts instead of calcium and magnesium salts. Some of these synthetic ion exchange materials can operate at elevated temperatures up to 100°C and under high *p*H conditions. In another method partial deionisation to reduce dissolved solids is carried out by passing the water through a bed of ion exchange resins in hydrogen ion form which converts carbonates and bicarbonates into carbonic acid; sulphates, nitrates and chlorides into their respective acids, and the cations are retained by the resin itself. The water is subsequently aerated to remove carbon dioxide and is either neutralized with sodium hydroxide to produce zero hardness water of low dissolved solid content or can be further treated by passing through a bed of anion exchange resin to remove all free acids. The water resulting from the latter treatment is demineralized water containing less than 5 mg/1 of total dissolved solids.

a) *Base exchange process* — This is the name given to the original method of softening water by zeolites. The name is still applied to the general process whereby sodium is substituted for another metal by means of exchange materials not necessarily of the zeolite class. Calcium and magnesium are retained by the exchange material and an equivalent amount of sodium salts passes out with water leaving the exchange unit. Once the exchange capacity is exhausted, regeneration is carried out with a strong solution of sodium chloride. By this process, sodium is replaced in the exchange material, calcium and magnesium chloride pass out to drain, and the cycle can be restarted. The advantages of the base exchange method of softening are that there is no sludge to be disposed of; that it can be operated under pressure; and that it is simple in operation. However, in general the quantity of water wasted in regeneration is considerable and there are certain other disadvantages also. With precipitation softening, the dissolved solids of the water are reduced but, with base exchange method, they are slightly increased and all carbonate hardness salts appear as sodium bicarbonate. Thus the alkalinity of the raw water is unaltered. Generally a base exchange softened water is more corrosive to iron and steel than water in the unsoftened state and a softened water containing a high sodium bicarbonate content may be unsuitable for some purposes, for example, laundry or boiler feed. These disadvantages can be overcome by the use of a split stream process which consists of dividing the water into two streams. One passes through a cation exchange resin in sodium form as in a base exchange process and the other through another cation exchange resin in the hydrogen form. The two treated streams are mixed and aerated to remove carbon dioxide. This process produces water of low dissolved solids and of any desired alkalinity. Many modifications of this process are available for various characteristics of the raw water.

b) *Cation exchange and anion exchange*

*Cation exchange* — It is the exchange of one cation for another. The types of exchange most frequently used in water treatment are the exchange of calcium and magnesium for sodium, as described in **5.1.1.2**(a), and the exchange of calcium, magnesium and sodium for hydrogen by means of hydrogen exchange materials. The exhausted exchange material is regenerated by passing a solution of mineral acid through the unit.

*Anion exchange* — In the anion exchange process, the sulphate ion, chloride ion, nitrate ion, etc, are exchanged by hydroxyl ion. This exchange is effected by passing the water through a bed of a synthetic anion exchange resin. In practice, anion exchange is usually applied only to waters that have previously been treated by hydrogen exchange process and hence anion exchange process may be regarded as the conversion of dilute solutions of mineral acids into water. The exhausted anion exchange resin is regenerated with caustic soda or soda ash and the waste sodium salts washed to drain.

c) *Demineralization* — Demineralization ( sometimes referred to as deionization ) is the process of cation exchange followed by anion exchange.

**5.1.1.3** *Distillation process* — Raw water is distilled in an evaporator and the distillate which is almost completely free from dissolved solids is used. As the evaporator itself may be considered as a very low pressure boiler, the feed may, under certain conditions, require softening. Distillation process is not generally required for low pressure boilers.

**5.1.2** *Internal Treatment* — When water has low hardness or a comparatively small quantity is required to be treated, an external water treatment plant becomes impracticable and uneconomical. Under such conditions internal treatment is applied. In this treatment, certain chemicals are administered direct to the water entering the boiler which cause the hardness producing salts to precipitate inside the boiler in the form of a smooth flowing sludge. Different waters require different chemicals. Sodium carbonate, sodium aluminate, sodium phosphate, tannin, starch and other compounds of vegetable or inorganic origin are used for this purposes. The sludge is removed when blowing down. This process is suitable for use particularly in low pressure boilers.

**5.2 Removal of Oil and Grease** — Oil and grease when finely dispersed in water are very hard to remove. The oil however, is easily trapped in a precipitate of aluminium hydroxide and effectively removed by sedimentation and filtration. In a lime-soda water softening plant sodium aluminate is used for producing a flocculant precipitate. The oil and grease present in water are enmeshed in the precipitate and are removed along with the precipitate of calcium and magnesium by sedimentation and filtration. When, however, the water is not softened by lime-soda process, a small amount of sodium aluminate or sodium carbonate and aluminium sulphate is added to the water to produce a precipitate of aluminium hydroxide, which enmeshes the oil and grease which is finally filtered.

**5.3 Conditioning** — A softening treatment may not always yield a water completely satisfactory for its purpose and the characteristics of the treated water, may, therefore, have to be modified. When such modification is used to render the treated water suitable, it is known as conditioning. The term is also applied to the modification of the characteristics of naturally occurring soft water the purity of which approaches that of an artificially softened water. Boiler feed water may be conditioned to protect (a) the boiler feed system and the boiler or (b) steam condensate system.

**5.3.1** *Conditioning to Protect the Boiler Feed System and the Boiler*

**5.3.1.1** *Against corrosion* — In most low pressure boilers, raising *p*H of boiler feed water prevents corrosion or reduces it to negligible proportions. The *p*H is raised by addition of an alkali. In some cases, for example, when internal treatment is in use, the main boiler water treatment may be utilized to protect the feed system ( and the boiler ) by feeding all or part of the treatment continuously through the feed system. If treatment with alkali is not completely satisfactory, then further treatment, either mechanical or chemical or both for boiler pressures above 20 MN/m$^2$ ( 20 kgf/cm$^2$ ), should be undertaken to remove dissolved oxygen. The chemical commonly used for this purpose is sodium sulphite which reacts with dissolved oxygen to form sodium sulphate. Recently certain amines are being used for removal of dissolved oxygen from boiler water. The most commonly used amine is hydrazine ( $N_2H_4$ ). This takes up dissolved oxygen from water and forms nitrogen and water. Thus dissolved solids in the boiler are not increased and oxygen is removed. Hydrazine, however, is much more expensive than sodium sulphite and increase in dissolved solids to a certain extent is not of very great importance in the operation of low pressure boilers, that is, below 2.0 MN/m$^2$, so sodium sulphite is generally used in these boilers. Even, in case of medium pressure boilers above 3.9 MN/m$^2$ pressure, the use of sodium sulphite is not recommended as it tends to break down into corrosive hydrogen sulphide, sulphur dioxide, etc, which corrode the boiler, steam and condensate systems and hence use of hydrazine is only recommended for the removal of traces of oxygen unremoved by thermal deaeration. If desuperheating ( DESH ) is practised, then the tapping point for DESH spray should be before the sodium sulphite dosing point.

**5.3.1.2** *Against deposition* — With any water containing hardness, there is a potential danger of deposition. Deposition in the boiler feed system may be reduced or eliminated by continuous or intermittent addition of small doses of organic or inorganic inhibitors such as tannin, phosphates, lignin, etc.

**5.3.2** *Conditioning to Protect Steam-Condensate System*

**5.3.2.1** *Against corrosion* — Oxygen and carbon dioxide passing over from the boiler with steam, cause corrosion of steam-condensate system when they redissolve in the condensate. In many plants, the amount of corrosion is unimportant but, if it becomes serious, oxygen shall be prevented from gaining access to the steam by removing dissolved oxygen from feed water before it enters the boiler. A recent development in the protection of condensate system from corrosion is the use of certain neutralizing amines such as morpholine, and cyclohexylamine. These are volatile organic chemicals of an alkaline character which, when added to a boiler, pass over with steam into the steam-condensate system. By virtue of their alkaline character, they are able to raise the $p$H of the condensate to assist in the reduction or elimination of corrosion in the condensate system.

**5.3.2.2** *Against deposition* — Scale formation in the generally accepted sense docs not occur in a steam-condensate system, although severe corrosion may cause a build-up of solids having the appearance of scale. Deposition may occur if carry-over takes place. Some entrainment of boiler water with steam occurs in all boilers. The amount is normally small but measurable. Entrainment of this type causes no trouble at the temperatures and pressures encountered in low pressure boilers, though heavy carry-over can cause deposition in superheaters and trouble with primemovers or in process. Mechanical preventive measures are frequently used but in those cases where the trouble is due to foaming, chemical treatment of boiler feed water with an antifoam material is advantageous. Antifoam chemicals are of complex nature and the mechanism by which they prevent foam formation is not precisely understood. However, there is an increasing volume of industrial experience to show that when correctly applied, antifoam materials are efficient in the prevention of steam contamination.

## 6. TREATMENT OF BOILER WATER

**6.1 Prevention of Scale** — There should be no hardness in boiler water. If the feed water is properly treated, this condition is maintained without difficulty. If hardness is observed in the boiler water, sodium phosphates should be used ( to remove it ) and some residual phosphate and proper $p$H should be maintained which would remove the residual hardness in boiler water.

**6.2 Prevention of Corrosion** — The first step in preventing corrosion in a boiler is to maintain an appropriate alkalinity in the boiler water. In most cases, the alkalinity present in a properly treated feed water is generally sufficient. ( The boiler water should have $p$H of about 11. ) If, however, corrosion in the boiler is not arrested by an adequate alkalinity, then the dissolved oxygen should be removed by addition of sodium sulphite or hydrazine.

**6.3 Prevention of Caustic Embrittlement** — Caustic embrittlement or intergranular cracking takes place only when the metal is under stress and a high concentration of caustic alkali is present. This can thus take place only on riveted and welded drums which have not been stress relieved. In modern practice, riveting is dying out and this difficulty will be avoided to a great extent.

**6.3.1** Caustic embrittlement can be prevented to a great extent if sodium sulphate is maintained in the boiler water. The quantity of sodium sulphate to be added to the boiler shall be such as would maintain a ratio about 2.5 with castic alkalinity ( as NaOH ) of the water present, in the boiler. As sodium sulphate is normally present in feed waters and also as sodium sulphite is injected into the boiler feed for the removal of dissolved oxygen which later converts itself into sodium sulphate, in many cases the ratio is maintained without addition of a further supply. If, however, the quantity is less and the ratio of sodium sulphate to caustic alkalinity ( as NaOH ) is found to be less than 2.5, it is necessary to add sodium sulphate to restore it. Sodium nitrate may also be used in place of sodium sulphate. The ratio sodium nitrate/total alkalinity ( as NaOH ) to be maintained in this case should be about 0.4.

**6.4 Concentration of Total Dissolved Solids** — The concentration of total dissolved solids in boiler water should be generally kept within the limits recommended below:

a) Boilers operating up to 2.0 MN/$m^2$ ( 20 kgf/$cm^2$ ) = 3 500 mg/1, *Max*

b) Boilers operating from 2.1 to 3.9 MN/$m^2$ (21 to 40 kgf/$cm^2$) = 2 500 mg/1, *Max*

c) Boilers operating from 4.0 to 5.9 MN/$m^2$ ( 41 to 60 kgf/$cm^2$ ) = 1 500 mg/1, *Max*

NOTE — For utility boilers where turbines are used the total dissolved solid content shall be dependent on the steam purity requirements.

Blow down of boilers may be intermittent or continuous as necessary to maintain the concentration of total solids within the above limits. Suspended solids also give rise to considerable trouble in the boiler and cause priming. Care should be taken to prevent their undue concentration by means of suitable blow down.

## 7. CARE OF BOILERS

**7.0** Although boiling out, initial boiler filling and protection of standing boilers have been described briefly, chemical cleaning of boilers is given in IS : 10391-1982*.

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*Code of practice for chemical cleaning of boilers.

**7.1 Boiling Out** — Before putting a boiler into service, it is necessary to remove all traces of oil and grease from the internal surface as it might lead to overheating and failure. For this purpose, it should be filled with clean water somewhat below the working water level and trisodium phosphate ( previously dissolved in suitable tank ) run in through the manhole as recommended below:

| *Chemical Used for Boiling Out* | *Amount in kg\1 000 litres of Water* |
|---|---|
| Crystalline trisodium phosphate ( $Na_3PO_4.12H_2O$ ) | 5 |
| or | |
| Anhydrous trisodium phosphate ( $Na_3PO_4$ ) | 2.2 |

NOTE — In case trisodium phosphate is not available, soda ash, 9 kg/1 000 litres of water, may be used.

The boiler shall be warmed through by a slow fire, keeping the manhole closed, immediately after adding the chemical and pressure allowed to rise slowly. It should be raised sufficiently to give a strong blow of steam at the air cocks. It should be allowed to cool and later blown down for about 15 seconds on each blow down valve and refilled to about 5 cm level in the gauge glass. On the following day, carry out the same process except that the pressure is raised to approximately 25 percent of the normal working pressure. On the third day carry out the same process and then drain the water as detailed below. When the pressure falls to 0.04 $MN/m^2$ ( 0.4 $kgf/cm^2$ ), the unit is blown down completely until it is empty, refilled to flood the drum and superheater and blown down again. It should then be carefully inspected. If any trace of oil or grease is observed, the process of boiling out should be repeated. If the boiler is found free from grease or oil or sediment, it should be closed and filled with feed water as specified in IS : 10392-1982*.

NOTE — If the superheater is non-drainable, it should be filled with only treated demineralised or condensate water.

**7.2 Initial Boiler Filling** — When a boiler is to be filled with water for service, it is desirable that normal feed water is used after proper softening. Sodium sulphate should also be added to ensure the safe ratio for prevention of caustic embrittlement.

**7.2.1** If normal feed would consist of a large portion of condensate and if the boiler is to be put into operation for the first time and no condensate is available, the best available water should be used after proper treatment, either external or internal. Sodium phosphate should be added to water as required to remove the residual hardness. The boiler should be blown down frequently to remove the sludge. Condensate should be collected and changeover to it should be made as soon as possible.

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*Specification for feed water and boiler water for low and medium pressure land boilers.

**7.3 Protection of Standing Boilers** — When boilers are temporarily at rest, they are liable to suffer from corrosion. If they are to be kept idle for more than a few hours, special measures, such as those given below, have to be taken to protect against corrosion during that period.

**7.3.1** *Short Periods* ( *Banked* ) — It is generally sufficient to keep the boiler on banked fire for short periods with water conditions that existed immediately prior to the shut down, provided the oxygen-containing feed water is not added after steaming has ceased. Alkalinity should be checked and sodium sulphite should be added if the shut down is to be of more than a few hours duration.

**7.3.2** *Extended Periods* ( *Wet Storage* ) — If the boiler is to be kept out of service for an indefinite period but at the same time it is desired to keep it ready for service, the boiler and the superheater should be completely filled with the normal feed water containing necessary alkalinity, and sodium sulphite ( or a mixture of hydrazine and ammonia ) should be added. Alkalinity and sodium sulphite ( or hydrazine-ammonia ) should be checked daily and an excess of sulphite ( or hydrazine-ammonia ) maintained. It can be put into immediate service on letting the water down to the working level in the boiler drums and draining the superheater.

NOTE — Wet storage is not advisable where there is any possibility of ambient temperature dropping to freezing point. If the system contains non-drainable portions, only ammonia and hydrozine should be used.

**7.3.3** *Extended Periods* ( *Dry Storage* ) — It is advisable to completely empty the boiler and dry thoroughly and remove all deposits to ensure that no moisture remains below them. Trays of quick lime or silica gel should be placed in the boiler drums before sealing them up. The amount of quick lime or silica gel required will be 1.5 $kg/m^2$ of boiler drum and tube volumes. Lime or silica gel should be changed from time to time.

## 8. CONTROL OF TREATMENT

**8.1 Testing** — It is absolutely necessary that raw water, softened water, feed water and boiler water are tested at regular intervals and records maintained. Routine tests on raw and softened water are few and simple. It should be the duty of some responsible person to examine these results interpret them and make necessary regulation in the chemical charges.

**8.1.1** The water softening plant should be kept clean and chemical proportioning gear and other mechanisms in good mechanical order. The softener-reaction tanks should be regularly desludged. The softener should, on no account, be operated above the maximum rating advised by the manufacturer.

**8.2 Blow Down** — The boiler should be blown down periodically to maintain the concentration of dissolved solids within recommended limits. Blow down is also based on silica content in boiler water. The quantity of water to be blown down is calculated as follows:

$$\text{Blow down} = \frac{100\,Y}{X - Y}$$

where

$Y$ = total dissolved solids in mg/l in feed water, and

$X$ = maximum permissible concentration in mg/l of total dissolved solids in boiler water.

Under all conditions, a small amount of continuous blow down may be desirable in addition to the periodical blow down to remove the precipitated sludge.

## 9. CHEMICAL COMPOSITION OF WATER

**9.1** Chemical composition of feed water and boiler water is given in IS : 10392-1982*.

## 10. COMPUTATION OF INITIAL DOSAGE OF CHEMICALS FOR TREATMENT OF WATER

**10.1** In order to guide the user, simple directions for computing the correct initial dosage of chemicals for treatment of water are given in Appendix A. This computation is based on regular chemical analysis of water and not on the control tests only. For detailed methods of test mentioned in Appendix A, reference may be made to relevant clauses of IS : 3025-1964† as given below:

| *Characteristic* | *Method of Test* |
|---|---|
| a) Carbonate hardness | 17 of IS : 6025-1964† |
| b) Magnesium hardness | Deduct calcium content ( as $CaCO_3$ ) determined according to **33.2** of IS : 3025-1964† from total hardness determined according to **16.1** of IS : 3025-1964† |
| c) Free carbon dioxide | **42** of IS : 3025-1964† |
| d) Non-carbonate hardness | **17** of IS : 3025-1964† |

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*Specification for feed water and boiler water for low and medium pressure land boilers.

†Methods of sampling and test ( physical and chemical ) for water used in industry.

# APPENDIX A

( *Clause* 10.1 )

## DIRECTIONS FOR COMPUTING DOSES OF CHEMICALS FOR TREATMENT OF WATER FOR LAND BOILERS

### A-1. CHEMICALS FOR PRECIPITATION SOFTENING

**A-1.1** The quantities given below are based on stoichiometric ratios of chemical reactions involved. In actual practice, a small excess over the theoretically required amount is found necessary to obtain best results and to maintain recommended alkalinity in feed water. In general a 5 percent excess is recommended. Where necessary, the charge may be further adjusted, as required, to obtain desired results.

**A-1.1.1** The quantities recommended are for pure chemicals. Commercials samples of lime vary considerably in their available lime content and this should be taken into consideration when calculating the dose. Same observations also apply to soda ash and sodium aluminate.

'a) *Lime*

1) *As Quick Lime.(* CaO )

Quick lime ( CaO ) to be added, kg/1 000 litres = 0.000 56 [ total alkalinity ( as $CaCO_3$ ) mg/l + magnesium hardness ( as $CaCO_3$ ) mg/l + free carbon dioxide ( as $CaCO_3$ ) mg/l ]

2) *As Hydrated Lime*

Hydrated lime to be added, kg/1 000 litres = 0.000 74 [ total alkalinity ( as $CaCO_3$ ) mg/l + magnesium hardness (as $CaCO_4$) mg/l + free carbon dioxide ( as $CaCO_3$ ) mg/l ]

b) *Soda Ash*

Soda ash to be added, kg/1 000 litres = 0.001 06 [ non-carbonate hardness ( as $CaCO_3$ ) mg/l ]

c) *Sodium Aluminate*

1) Up to total hardness ( as $CaCO_3$ ) of 200 mg/l sodium aluminate to be added, kg/1 000 litres = 0.02

2) Total hardness ( as $CaCO_3$ ) above 200 mg/l sodium aluminate to be added, kg/1 000 litres = 0.03

## A-2. OTHER CHEMICALS

**A-2.1** When sodium phosphate, sodium sulphate or sodium sulphite are to be used, sufficient quantities are to be added to maintain their desired concentration in water.

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